Third Progress Report 1959-1960

COOPERATIVE SNOW MANAGEMENT RESEARCH

SNOW STUDY AREAS AND SNOW ZONE IN CALIFORNIA, 1960

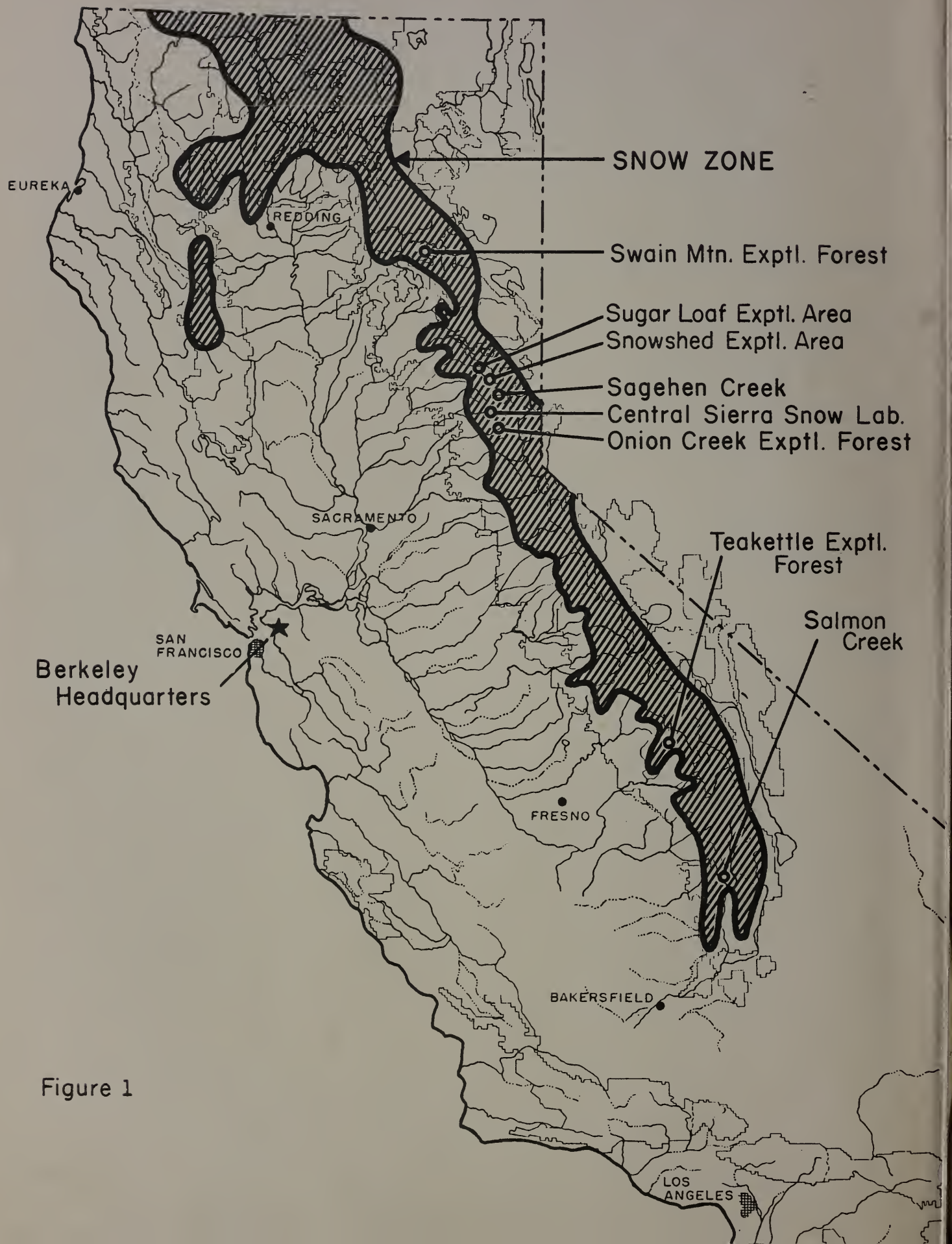

Figure 1

June 30, 1960

THIRD PROGRESS REPORT, 1959-60

CALIFORNIA COOPERATIVE SNOW MANAGEMENT RESEARCH

by

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with cooperation of

State of California, Department of Water Resources

CONTENTS

1/ Pages 1 through 56 are contained in the 1957-58 Progress Report, pages 57 through 94 in the 1958-59 Progress Report.

SUMMARY

In July 1956, the Forest Service with the cooperation of the State of California started watershed management research in California's snow zone. The purpose of the research was to expand the present body of knowledge and develop and test ways of managing California's watersheds for improvement of water yield. Two formal progress reports precede this report: The 1957-58 Progress Report (11) gives detailed objectives and methods of the eighteen separate studies then under way and progress for the first two years of the study. The second Progress Report, the 1958-59 report gives progress for that year. This report gives results for the fourth year of the study in the sixteen studies still under way.

Nine technical papers and one summary paper were published during the past year on subjects ranging from snow zone forest inventories to logging effects on snow.

Snow has been measured at some ninety-one snow courses, representing many conditions of natural forest stands, forests logged in a variety of ways, and brushfields, both natural and cleared.

Soil moisture losses during summer have been measured at some three hundred points, representing a wide span of forest sites--different slopes, forest conditions, types of logging, methods of slash disposal, and natural and cleared brushfields.

Winter evaporation losses from snow have been measured in forest stands and openings, in large meadows, on exposed ridges, and on different slopes.

Streamflow and sediment measurements were continued in eleven experimental watersheds, one of which was partly logged last year and the logging effects on streamflow and sedimentation have been evaluated.

This was a year of moderately light snowpack, following the very light snowpack year of 1959 and the extremely heavy snowpack year of 1958.

Plans for the coming year are to sharply curtail field work in the studies in which we now have the three years of data--the snow, soil moisture, and winter evaporation loss measurements under natural conditions of forest densities and openings, and to concentrate the field work on plot tests of various management alternatives, forests logged in various ways and brushfields cleared and treated in various ways. Continued emphasis will be placed on analyzing data currently and publishing results.

Financing and cooperation in the project are such as to make for rapid progress. The State's contribution for the research was $68,500 this year. The Forest Service has matched this amount and conducted the research. Other agencies continued to lend a hand: Pacific Gas and Electric Company, the Weather Bureau, and the Department of Zoology at the University of California.

Reprints of published papers are available, and other information is available upon request. To make this information more accessible, a detailed index has been included as part of this report. Inasmuch as this is to a large extent a continuation report, pages numbered herein start with page 95.

THIRD PROGRESS REPORT, 1959-60

CALIFORNIA COOPERATIVE SNOW MANAGEMENT RESEARCH

by

Henry W. Anderson and Lucille G. Richards

INTRODUCTION

Studies are under way in California's snow zone to expand the present body of knowledge of watershed management effects on water yield, water quality, floods, and sedimentation. The studies are being made by the Pacific Southwest (formerly California) Forest and Range Experiment Station of the U. S. Forest Service with the cooperation of the Department of Water Resources of the State of California.

To the end that future land managers can make decisions on water management with greater accuracy and with more confidence, Snow Management research aims are to:

1. Suggest methods of land management for maintaining or improving water yield or water quality.

2. Test a variety of methods which offer promise of desirable effects or threat of adverse effects on water yield or control, and

3. Lead to further understanding of the basic hydrologic processes of how water is received and discharged to the end that the effects can be predicted for wide spans of forest land management practices upon water yield and water control.

KINDS OF STUDIES

This is a report of progress during 1959-60 in each of sixteen studies now under way and an outline of objectives and methods for two new studies about to be started. The objectives of the eighteen original studies and the methods used in each study were outlined in detail in the 1957-58 Progress Report (11). Progress and plans in 1958-59 were outlined in the second Progress Report (25). This report will concentrate primarily on results and future plans. The studies are four kinds:

1. Inventories of present conditions of:

Water yield	(Study No. 1-10),
Land conditions	(Studies No. 1-1, 1-5),
Soil erodibility	(Study No. 1-18).

2. Studies of basic meteorology, snow, and heat balance (Studies No. 1-6, 1-9, 1-14).

3. Development and testing of methods of improving water yield and controlling sediment (Studies No. 1-4, 1-7, 1-8, 1-11, 1-13, 1-15, 1-16, 1-19, 1-20).

4. Pilot tests of various forest and land management methods on experimental watersheds for their effects on streamflow and sedimentation (Studies No. 1-2, 1-3, 1-12, 1-17).

Detailed plans of these studies are available for inspection upon request.

The study areas are shown in Figure 1.

INDIVIDUAL STUDIES

Inventory of Sierra Hydrologic Characteristics (Study No. 1-1)

The Sierra west-side is made up of 42 parts forest, 29 parts bare ground, and 17 parts brush, seasoned with 7 parts grass-herb, and sprinkled with 5 parts lakes, crops or talus (26). The southern half of the Sierra has more forest area, but forests are less dense than in the north half. The dense forests are mostly at elevations below 7,000 feet. Most of the brush is in the north; most of the bare area is in the south, particularly in the Kings River basin. These and other results have been summarized in a publication by Richards (26).

Plans--To summarize the forest density and cover information by major river basins of the Sierra west-side.

Onion Creek Experimental Watersheds (Study No. 1-2)

At five high elevation watersheds streamflow and sedimentation have been measured for 2 years. Peak discharges in the watersheds were nearly identical in the first high runoff year of 1958 and in the low runoff year of 1959. Annual discharge in 1958 ranged from 52 to 59 inches. For 1959 annual discharges together with maximum discharges of the year are given below:

Watershed	Drainage Area sq. mi.	Maximum Yearly Discharge cfs/sq.mi.	Annual Flow, 1959 inches
Onion Creek No. 1	0.19	10	13.7
No. 2	0.48	16	19.2
No. 3	0.65	11	17.2
No. 5	0.39	20	17.1
No. 7	0.80	12	16.4

Daily discharge records for watershed No. 1 for the water year 1958 are published in USGS Water Supply Paper No. 1565. Provisional daily records for all watersheds for the water year 1959 are available upon request.

Reservoir sedimentation in the low runoff year 1959 was slight. Deposition range from 0.00 to 0.07 A.F./sq. mi. Suspended sediment outflow was measured using an automatic sediment sampler at weir No. 3 (File Report No. 7).

Plans--The plans are to continue gaging these streams and measuring sediment inflow and outflow for another 3 years before logging the watershed to evaluate logging effects.

We plan to continue our arrangement with the USGS in inspecting the records and publishing the results in their regular Water Supply Papers.

Streamgaging and Sediment Measurements at Teakettle Experimental Watersheds, Kings River (Study No. 1-3)

At another set of five small watersheds in the southern Sierra, streamflow and sedimentation were measured for another year. Here too, peak flows were nearly identical in 1959 with those reported in 1958, ranging from 7 to 21 cfs/sq. mi. in both years. Maximum discharges for 1959 and annual flow for 1958 and 1959 are given below:

Watershed	Drainage Area	Maximum Discharge, 1959	Annual Flow 1958	Annual Flow 1959
	sq. mi.	cfs/sq.mi.	- inches -	
Teakettle No. 1	0.77	10	32.4	10.4
No. 2	0.85	10	31.4	8.0
No. 2A	0.27	9	34.2	6.7
No. 3	0.86	21	32.2	10.2
No. 7	0.11	7	28.4	4.9

Daily discharges for the water year 1958 for all watersheds are published in the USGS Water Supply Paper No. 1565. Provisional daily discharges for water year 1959 are available upon request.

Sediment deposition for the watersheds was very low in 1959, ranging from 0.0 to 0.003 A.F./sq. mi. Watershed characteristics and number of suspended sediment measurements are given in Table 2 at the end of this report. An automatic suspended sediment sampler to measure sediment outflow is being tested at weir No. 3 (File Report No. 7).

Sediment productions for year 1957-58 (page 81) should be corrected for sluicing to: No. 1, 0.062; No. 2, 0.019 and No. 3, 0.024 A.F./sq. mi. In the others sluicing was negligible.

A soil-vegetation survey of the watershed area has been completed as part of the soil-vegetation Station survey of Fresno County by our Economics Division under funds furnished by the California State Division of Forestry.

Plans--We plan to continue to gage the watershed and measure sediment for at least two more years before applying various logging methods and testing the effects on streamflow and sedimentation. Soil-vegetation information will be worked up to guide application of the tests.

Cooperation--The Pacific Gas and Electric Company has generously cooperated in servicing these Teakettle gaging stations during the winter months.

Inventory of Forest Conditions at the Central Sierra Snow Laboratory Snow Courses (Study No. 1-4)

This study is complete. Any further studies of the evaluation of forest conditions will be carried on under Study 1-11.

The results of these studies have been published in three papers. (See publications numbers 1, 6, and 14, at the end of this report.)

Soil-Vegetation Surveys of Castle Creek Laboratory Basin Study No. 1-5)

This study is complete. The results were published in publication number 5. (See publications list at the end of this report.)

Further summaries of the information on timber stand densities, volumes, and area of brush and open in the Castle Creek watershed have been compiled. These are summarized in Tables 1 and 3 at the end of this report. In general, forest conditions in the Castle Creek basin correspond fairly closely to the averages for the Sierra west-side (26). In Castle Creek basin forest cover is 46.8 percent, bare area is 30.5 percent, brush covered area is 14.0 percent, and grass-herb is 3.8 percent, and miscellaneous 4.9 percent.

Basic Meteorological and Snow Measurements, Central Sierra Snow Laboratory (Study No. 1-6)

Meteorological and snow records taken in and near the Central Sierra Snow Laboratory since the program began in July 1956, together with the status of data processing are shown in Table 4, Appendix A. Daily records for the CSSL Headquarters for the period July 1, 1959 to June 30, 1960, are given in Figure 2, Appendix B, and monthly summaries are given in Table 5, Appendix A. Daily streamflow for Castle Creek for the same period is shown in Figure 3, Appendix B.

Some preliminary tests were made of the use of the radioactive soil moisture probe in determining the water content (density) of snowpacks. Average snow-water contents as determined by the standard Mt. Rose snow tube and by the nuclear probe were identical in the first test; further testing is needed, for layer by layer wide differences in the density between the two measurement methods were found.

Cooperation--The Weather Bureau is cooperating in the studies by taking wind direction and velocity measurements for us at their Blue Canyon Station, 20 miles west of the laboratory at an elevation of 5,000 feet. We, in turn, are supplying daily meteorological, snow, and streamflow data to them which are used in the State Flood Forecasting Service. We are also supplying samples of streamflow, of new snow, and of precipitation to the State Department of Public Health for analyses of radioactivity.

Plans--We plan to continue the basic meteorological measurements as at present until analyses indicate that some of the stations may be dropped. We will explore further the possibility of using the radioactive soil moisture probe in the measurement of snow density profiles.

In the new plot studies at the Snowshed Area (Yuba Pass), at the Sugar Loaf (Downieville) study area, and at the Salmon Creek (Kern Plateau) studies, we will install storage gages to measure precipitation at these sites.

Wind Effects on Snow Accumulation in the Forest (Study No. 1-7)

This study was inoperative during the year, except for installation of tree-top brackets for suspending anemometer and other meteorological instruments within and adjacent to two forest openings in the Castle Creek basin.

Plans--Further analyses will be made of the relationship of shelter from wind and eddying of wind by forest cover to snow accumulation and melt in the some ninety snow courses measured during 1957-58 through 1959-60.

Cooperation--This study has been strengthened by the cooperation of the Weather Bureau in servicing and operating our wind recording instruments at their Blue Canyon site and working up hourly wind records at that site.

Hydrologic Processes and Erosion Measurements, Onion Creek Watersheds (Study No. 1-8)

Summer soil moisture losses and snow accumulation and melt were measured in a logged and unlogged forest and in a brushfield. The logging was a "commercial diameter-limit cut" in which all trees greater than 18 inches in diameter were removed. Comparison of snow accumulation and melt of the cut and uncut forest for various dates in 1960 is given below:

Treatment	Water Equivalent - Inches		
	Feb. 28	March 6	May 4
Forest uncut	21.5	17.0	11.0
Forest cut	25.0	27.5	11.0
Difference	+ 4.5	+10.5	0

Again in 1960 as in 1958 and 1959 there was more water left at the time of maximum pack in the cut forest than in the uncut. In this year there were 10.5 inches more. And again snowmelt in the cut area was faster so there were equal amounts left on May 4 in the cut and uncut forest. If a more rapid melt in the cut forest continued, the last snow would be found in this case in the uncut forest.

Summer soil moisture losses were 0.8 inches less in the cut forest than in the uncut forest, with the losses being 9.0 inches in the unlogged forest and 8.2 inches in the logged forest. The differences were nearly identical to those of 1958; however, total losses in both logged and unlogged were about 1 inch greater in 1959 than in 1958 (31).

Snow accumulation and melt during the winters of 1959 and 1960 at the Onion Creek brush plots (elevation 6,800 feet) are summarized below:

Year and Site	Water Equivalent - Inches		
1959	March 9	April 6	May 5
Block C, Level ridge	23.0	15.7	3.6
Block D, 24% W slope	9.7	2.8	0.0
Block E, 21% SE slope	22.6	15.7	2.0
Average	18.4	11.4	1.9
1960	March 4	April 6	May 4
Block C, Level ridge	23.8	20.0	6.0
Block D, 24% W slope	15.6	6.6	0.4
Block E, 21% SE slope	29.9	26.0	9.7
Average	23.1	17.5	5.4

Maximum snow-water accumulation under the brush was 2 to 4 inches less than under forest in 1959.

Basic Meteorological and Snow Measurements, Teakettle Experimental Area (Study No. 1-9)

The Pacific Gas and Electric Company again this year made regular weather observations and measurements for us at the station near Wishon Dam. These measurements are proving useful in working up our streamflow measurements at the Teakettle watersheds and will serve to characterize the years of the studies in these watersheds.

Plans--Meteorological measurements are needed in this area for at least one more year--until such time as adequate correlations with long-term weather stations can be established.

Water Yield (Study No. 1-10)

This study, which has been in its data collecting phase, will get into the analysis phase this year to the end that snow zone water will be evaluated as to amounts and timing of delivery of water.

Heat Equivalent and Snow in Openings and Forest Slopes
(Study No. 1-11)

Three years of snow measurements at from 81 to 90 sites have been summarized to give the maximum snowpack water each year for slopes of different kinds, forest openings of different sizes and forests of different densities (Table 7). The data have been adjusted to give estimated snow water near the maximum snowpack--April 22, 1958, and April 1, 1959. The adjustment was accomplished by using the degree-day factor for each course or part of course and extrapolation backward to the date of the maximum pack (1). The data were adjusted to a common elevation, 7,000 feet, by using 2.16 inches per 100 feet in 1958 and 1.20 inches per 100 feet in 1959. The elevation of each course is given so these adjustments may be eliminated as needed in some analyses. With these adjustments, we feel that the effects of slope, aspect and forest conditions on the snowpack can be directly compared.

The wide differences in maximum snowpack on north and south slopes are clear indications of winter melt. Average snow water in forest and openings on various slopes on April 22, 1958 and April 1, 1959 were:

Topography	Snow Water					
	In Opening		In Surrounding Forest		Average	
	inches					
	1958	1959	1958	1959	1958	1959
North Slopes	67.2	31.2	59.8	25.0	63.5	28.1
Level	64.0	28.8	59.0	23.8	62.5	26.3
West Slopes	60.5	25.5	54.8	23.2	57.6	24.4
East Slopes	60.8	25.8	52.8	20.8	56.8	23.3
South Slopes	56.8	20.0	51.8	17.8	54.3	18.9

Openings had 2.2 to 8.4 inches more snow water than the surrounding forest at the time of maximum pack, with only the south and west slopes showing significantly less difference in the "dry year" of 1959 than in the very "wet year" of 1958.

Effect of size of trees

Do the different sizes of trees affect the amount of snow left in the spring? To answer this question the snow data on June 1, 1958 for all sizes of openings were summarized for east and west slopes and level areas and are given below:

Size of Tree	June 1, 1958 Snow Water		
	In Opening	In Forest	Average
Small (15-60 feet)	32.5	26.5	29.5
Medium (60-100 feet)	35.5	22.5	29.0
Large (>100 feet)	28.0	31.5	29.0

These data indicate that the size of tree is not important in affecting the average snow water left in spring in openings and adjacent forests.

Thin stands versus openings compared

By comparing forests of 50 percent density with the average of 50-50 forest and open, a clue to the effects of selection versus strip or block clear cutting may be obtained:

Condition and Year	Snow Water		
	April 22	June 1	Melt
	- - - - - - inches - - - - - - -		
1958			
50 percent density	53.4	25.0	28.4
50-50 forest-open	60.8	26.0	34.8
Difference	+ 7.4	+ 1.0	+ 6.4
1959	April 1	May 10	Melt
50 percent density	21.5	8.7	12.8
50-50 forest-open	24.4	9.2	15.2
Difference	+ 2.9	+ 0.5	+ 2.4

The strip or block clear cutting seems to have the advantage in maximum snow accumulated but faster melt so the snow left on June 1, 1958 and May 10, 1959 was only slightly less in 50 percent dense forest than in the 50-50 forest and open.

Streamflow and Sediment Measurements, Castle Creek (Study No. 1-12)

One square mile of the 4 square mile Castle Creek Basin was selectively logged in the summer of 1958. Most of the trees greater than 20 inches in diameter were taken. A good stand of pole-size trees and reproduction was left. Original timber types and volumes and volume cut are summarized in Table 1. What were the effects on water and sediment delivery from the watershed?

Water yielded as streamflow was apparently increased the first year after logging--374 AF more water was delivered than would have been expected without the logging. The water yield from Castle Creek and the South Fork of the Yuba (51 sq. mi.), for two "dry" years before the logging (1947 and 1949) was used as a control and compared with the similar year after the logging (1959):

Year	Yuba River AF	Castle Cr. AF	Difference AF	Ratio C/Diff.
Annual Streamflow				
1947	88,170	6,350	81,820	0.0775
1949	97,400	6,920	90,480	0.0766
		Average		0.0770
1959	80,030	6,074	73,956	
Expected streamflow wo/logging		5,700		
Logging effect		+ 374 AF ± 20 AF		
June Streamflow				
1947	7,510	604	6,906	0.0872
1949	8,420	788	7,632	0.1032
		Average		0.0952
1959	6,290	744	5,446	
Expected streamflow wo/logging		517		
Logging effect June flow		+ 227 AF ± 44 AF		

We see that the indicated effect of the logging was to increase the annual water yield by 374 AF which is equivalent to 1.75 ± 0.09 inches of yield over the watershed. This is equivalent to 7.0 inches in the logged area.

The indications are that about half of this increase was delivered in the month of June, amounting to about a 40 percent increase in the expected June flow for that dry year.

Sediment production from the watershed was also definitely up. The sediment-discharge relation before logging was given in Figure 4 of the 1958-59 Progress Report (25). The post logging sediment data and the change in sediment production associated with the logging for first and second year after logging are given in Figure 5 of this report.

An analysis of the actual flows of the year 1959 and the sediment-discharge relations before and the first year after logging indicate that for 1959 the average sediment concentration was 66 ppm, and production was 140 tons per square mile; the predicted concentration without logging would have been 32 ppm, and the total production 64 tons per square mile. For the 4 square mile watershed, the sediment was increased 76 x 4 or 300 tons in this low water year.

For some purposes sediment production in an average year rather than the particular year is what is wanted. A method of estimating this is illustrated in Table 6.1/

Jim Wallis has computed the average long-term sediment production before logging and the first and second year after logging, assuming that a normal streamflow occurred each year.

	Suspended Sediment Production	
	ppm	Tons/sq. mi. yr.
Before logging (1957-58)	65	234
1st year after logging (1958-59)	327	1,286
2nd year after logging (1959-60)	117	455

There was an indicated five-fold increase the first year after logging; however, there appears to have been a marked decrease in sediment the second year after logging despite a small amount of re-logging in the watershed in the late fall of 1959.

Probably of most significance was the indication that logging of the commercial trees in about 1/4 of a watershed apparently increased flow about 6-1/2 percent in a critically dry year.

Plans--Ray Rice is analyzing the snow, soil moisture, and data of ground and canopy cover in interpreting causes of the streamflow and sediment difference found. We will evaluate the effect of the additional logging in late 1959 on streamflow. Data on streambank, bare soil and erosion indicators will be collected to try to evaluate where sediment sources are. Data on snow accumulation and melt and on soil moisture losses will continue to be taken to evaluate how streamflow effects came about.

1/ Trans. Amer. Geophys. Union 35(2):270, 1954.

The construction of the freeway across the basin will give an opportunity to evaluate its effects on snow accumulation and melt and on streamflow and sedimentation. Three snow courses transecting the freeway were established and one year and part of second year pre-construction measurements have been taken. We plan to continue these. Samples of stream sedimentation above and below the proposed freeway have been taken so as to isolate the freeway effects from logging effects on sedimentation.

Winter Evapotranspiration in Relation to Forest and Terrain Characteristics (Study No. 1-13)

This year evaporation from snow was measured in forest openings of four sizes: Opening 1/2 to 1 times as wide as the tree heights, 1-2, 2-4 and greater than 4 tree heights across. Wind at 1 foot above the snow was also measured. Results for a day with steady south and southwest winds (Mar. 5-9, 1960) showed evaporation as follows:

Size Opening	Average Daily Wind Miles/day	Average Daily Evaporation Inches/day
1/2-1 tree height across	39	0.015
1-2 " " "	35	0.016
2-4 " " "	45	0.021
>4 " " "	115	0.030

Evaporation was closely related to wind. In the two larger size openings evaporation was distinctly less in the sheltered southwest side of the opening and greatest in the exposed northeast side, with the center intermediate in value. In the two smaller openings evaporation was nearly the same in all parts of the opening.

Evaporation for a 10-day period in March 1960 averaged 0.020 inches per day for forest openings.

Plans--Plans are to discontinue snow evaporation measurements except where readings are needed in evaluating heat balances. Al West will summarize and publish his results for the three-year study.

Heat Balance Components in Forest and Openings (Study No. 1-14)

Progress has been made in instrumentation for measurements of radiation inflow and outflow and for conductive and convective heat exchange at and near three forest openings. Cables for suspension of instruments in forest openings and brackets for suspension of instruments from trees adjacent to openings have been installed.

Plans--We plan to first test all instruments in the forest opening near the CSSL Headquarters, then take periodic sample measurements of the heat components in the other forest sites. We will work with Bert Goodell of the Rocky Mountain Experiment Station in testing various radiation instruments for possible use in measuring heat at forest sites.

Evaluation of Summer Evapotranspiration in Relation to Forest Sites (Study No. 1-15)

Summer water losses for the years 1958 and 1959 have been measured at 37 sites, representing various forest stand conditions near the Central Sierra Snow Laboratory. Soil moisture losses varied widely with forest types according to Knoerr. These losses were as follows for the top 4 feet of soil:

Condition	: Summer Soil Moisture Loss
	Inches
Bare	2.0
Low Density Red Fir	5.2
Forest Opening Without Reproduction	5.6
Wyethia (Wild Sunflower)	7.6
Dense Old and Young Red Fir and Openings with Reproduction	7.6
Very Dense Reproduction	10.4

Additional losses of 2.0 inches of summer precipitation occurred at each site.

Plans--Knoerr will report details of his analyses of these data by soil depths, including relations which indicate that summer losses can be computed from meteorological data.

Swain Mountain Snow and Soil Moisture Studies (Study No. 1-16)

Snow accumulation and melt and summer evapotranspiration losses were measured in a forest cut in two ways and in uncut forests. The forest had been cut in strips 5 chains wide (2 tree heights across) and in a block cut area of 17 acres. Summer soil moisture losses in 1959 for a 4-foot deep soil (the average soil depth) are shown in the following tabulation:

Condition	Soil Moisture Loss
	Inches
Strip Cutting	
Cut	3.6
Uncut	7.7
Difference	4.1
Block Cutting	
Cut	5.8
Uncut	9.2
Difference	3.4

These summer soil moisture losses in 1959 in the uncut forest were 1 to 2 inches greater than in 1958; the differences between cut and uncut forests were also about 0.7 to 0.9 inches greater (31).

The effects of slash treatment on water losses in summer of 1959 were (31):

Slash Treatment	Soil Moisture Loss	Summer Precipitation	Total Loss
	Inches		
Piled and burned	3.2	0.5	3.7
Left where it fell	3.8	0.5	4.3

Combined interception and evaporation from the soil was 0.6 inches less in the bare soil area created by piling and burning of the slash than in the untreated area. In other years with different amounts or time of occurrence of precipitation the effects might be quite different.

Plans--We plan to continue snow and soil moisture loss measurements with the cooperation of our Forest Management Research Division.

Sagehen Cooperative Study of Streamflow, Sedimentation, and Fish Habitat (Study No. 1-17)

Part of the studies in this area are of brushfield conversion.

Again this year summer water losses were measured in a brushfield being converted to a pine forest. In 1958 the brush was removed from a 12 percent, south slope, by bulldozing and windrowing the brush; pine was planted. Summer soil moisture losses in the period May 25, 1959 to October 14, 1959 are given in the following tabulation:

Condition	Soil Moisture Loss 4-foot Soil	Summer Precipitation	Total Loss
	- - - - - - - - - Inches - - - - - - - - -		
Converted Brush (to small pine)	1.7	2.7	4.4
Unconverted Natural Brush	4.9	2.7	7.6
Difference	3.2	-	3.2

Thus, the conversion saved 3.2 inches of water for a 4-foot soil. For the two summers, 1958 and 1959, the conversion saved an average of 3.0 inches of water per year for a 4-foot soil and in places where the soil was 7-foot deep, 8-1/2 inches were saved.

Fifty-three measurements of suspended sediment concentration have been made in Sagehen Creek (10.9 sq. mi.) in the last two years. Sediment concentration is poorly related to discharge so average concentration times long-term average flow has been used to estimate sediment production. Suspended sediment discharge for an average annual discharge of 11.2 cfs is 7.4 tons per sq. mi. per year--a very low value.

Plans--Continue present measurements and take soil moisture measurements in an adjacent forest stand in an attempt to anticipate losses when the planted pine "grow up."

Erodibility of California Wildland Soils, Relation to Sedimentation (Study No. 1-18)

Andre' has made multiple regression and covariance analyses of the relation of erodibility indexes of California wildland soils to geology, vegetation, elevation and geographic zone which give promise of useful results.

Geologic rock type was by far the most important source of differences in soil erodibility.

Soil differences associated with vegetation showed grassland soils least erodible, forest-land soils next and brushland soils most erodible. Although erodibility was well indexed by these variables, still erodibility was highest in the Central Coastal zone, next erodible in the Sierra and least erodible on the North Coast. Correlation coefficients between erodibility indexes and these soil forming factors exceeded 0.99.

Jim Wallis used 20 of the soils with the greatest differences in erodibility to test whether these differences were "caused by" differences in the cation status of the soils. His report (File Report 8) showsdefinite decreases in two erodibility indexes associated with increasing calcium and magnesium base status.

Suspended sediment discharge from 60 California watersheds have been computed and some topographic parameters of these determined.

Plans--Make a study of the relation of base exchange status to erodibility index for the major geologic types. Relate suspended sediment discharge from 60 California watersheds to soil, streamflow, topography and vegetation condition. Relate reservoir deposition to suspended sediment, reservoir capacity and soil-geologic variables in watersheds. Publish parts of these results of this study as they become available.

Summer Water Loss as Related to Time Following Logging and Associated Vegetation Recovery (Study No. 1-19)

This is a new study to be started July 1, 1960.

Objectives--To study the changes in soil moisture losses associated with time after logging. To evaluate how these changes are related to revegetation of the area, distance from vegetation, and shade, and back radiation from vegetation.

Methods--Changes in soil moisture storage at the start of summer and at various times throughout the summer will be measured using a radioactive soil moisture probe. Sites will be chosen, representing different sizes of forest opening and different times following logging, 1-2 years, 5-6, 9-10 and greater than 14 years. In these openings and in the adjacent forests, access tubes will be sunk to bed-rock; soil moisture will be measured at about monthly intervals starting in early summer and ending when the soil moisture becomes recharged in the fall. Soil moisture changes when corrected by adding summer precipitation will give summer water losses.

Plans--This study will be conducted for one or two summers, concentrating the first year on logged areas near the Central Sierra Snow Laboratory.

Yuba Pass (Snowshed) Plot Tests of Logging and Slash Treatment Effects (Study No. 1-20)

This is another new study to be initiated this year. The study site is in the 7.6 square mile Miller Creek basin in the headwaters of the Feather River, 7 miles west of Sierraville California (Figure 1). Here a 300 acre tract has been selected for management-size tests of cutting of forests for water yield.

Objectives--The objectives of this study are to:

1. Test the practicality of logging of red fir forest in patterns designed to maximize snow accumulation and improve water yield.

2. To compare the results of cutting patterns and slash disposal methods aimed at improving water yield with ordinary, or conventional logging methods on snow accumulation, soil moisture losses, erosion indicators, and estimated water yield, by measurements taken at the logging sites.

3. To measure and evaluate the resulting effects on streamflow predicted from the surface measurements at the logging sites and that obtained from measurements of the stream at the gaging station.

Scope--This study is intended primarily as a practical-size test of various logging and other management methods on factors related to water yield. It is not intended that this be the final test of the effects of logging on streamflow and sedimentation; rather this is the preliminary step to tests of various methods on experimental watersheds.

Methods--The effects of cutting different strip widths, and selective cutting, treatment of residual stand and of slash disposal on snow accumulation and melt, on soil moisture loss, and on sediment production, will be measured at the treatment sites. The effects on sediment production will be measured in the runoff from small tributaries each with a single treatment. The effect on streamflow will be evaluated in toto by measurements at the single gaging station.

Treatments--In the first phase of the study the following eight treatments will be evaluated:

1. Clear cutting of east-west strips 2 and 4 chains wide, with the slash lopped.

2. Clear cut strips 2 and 4 chains wide, slash dozed and burned.

3. Clear cut strips 2 and 4 chains wide, with slash dozed to the downhill edge of the strip.

4. Clear cut strips, except the residual stands left, slash lopped.

5. "Ideal forest cutting" with a wall of trees to the south and the steps of smaller trees to the north, cut strip clear cut, slash dozed and burned in one half, piled downhill in other half.

6. Selectively cut area, overstory of trees to 24 inches in diameter, slash lopped.

7. Selectively cut stand, small trees only left in stands, slash lopped.

8. Clear cut area, slash lopped (resembling block cut).

Plans--We plan to lay out the treatment areas on the ground this fall, and to take pre-treatment measurements of soil moisture loss this summer, and snow measurements next winter. Then the treatments will be applied next summer.

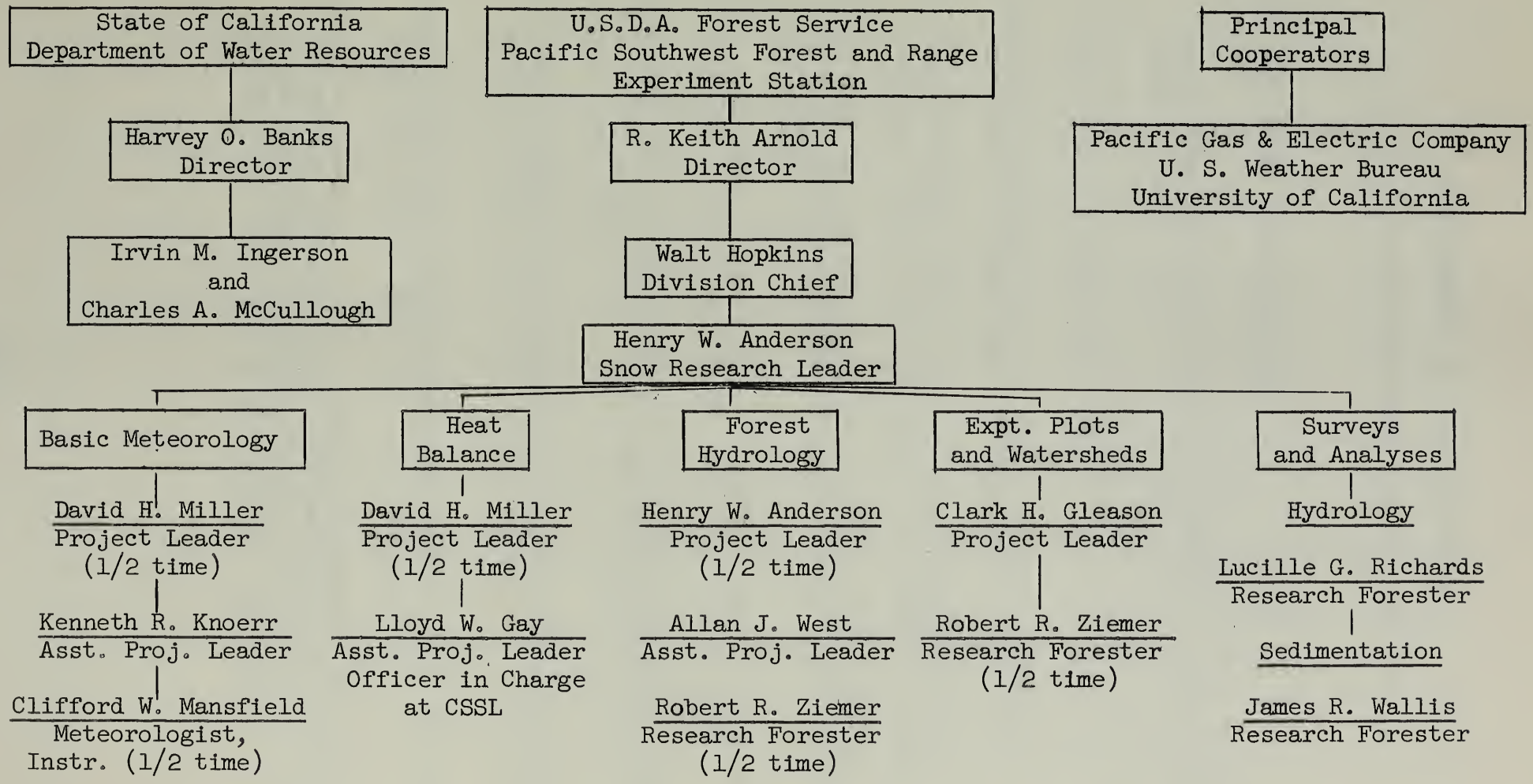
Cooperation--The Tahoe National Forest is cooperating by conducting the sale and assisting in the layout and application of the treatments.

ORGANIZATION

The organization of the California Cooperative Snow Management Research is shown on the next page. In all, ten technicians are working directly on the project, one of them, half time. About an equal number of forestry aids and other field and office assistants help keep the project running.

ORGANIZATION CHART - CALIFORNIA COOPERATIVE

SNOW MANAGEMENT RESEARCH 1960-61



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R. M. Miller, Data Processing

Admin. Services: F. W. Bacon, Chief, Divn. Station Management

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APPENDICES

A. TABLES

B. FIGURES

C. REPRINTS, selected 1959-60 publications

APPENDIX A

TABLES 1-7

Table 1.--Timber types and commercial timber volumes, Castle Creek Basin, 1957[1/]

Type	Crown Density	Area	Volume
	percent	percent	fbm/1000
Non-stocked	0	47.8	0
Young	20-80	12.9	705
Young-old	50-80	4.3	4,274
Young-old	20-50	18.7	14,122
Young-old	5-20	9.9	3,230
Old-young	50-80	2.2	5,335
Old-young	20-50	3.8	3,684
Old-young	5-20	0.4	36
		100.0	31,386

1/ Twenty-four percent of area was cut over in 1958 removing 2,855,000 fbm and additional relogging in 1959 removed 150,000 fbm of above volumes.

Table 2.--Suspended sediment sampling in experimental watersheds

Name		Major River Basin	Drainage Area	Date of First Sample	No. of Samples
			Sq. mi.		
Teakettle	No. 1	N. Fk. Kings	0.77	5-30-58	1
	No. 2	N. Fk. Kings	0.85	5-29-58	2
	No. 2a	N. Fk. Kings	0.27	5-29-58	2
	No. 3	N. Fk. Kings	0.86	5-29-58	27
	No. 7	N. Fk. Kings	1/ 0.11	-	0
Onion Creek	No. 1	N. Fk. American	0.19	5-24-58	22
	No. 2	N. Fk. American	0.48	5-24-58	24
	No. 3	N. Fk. American	0.65	5-24-58	66
	No. 5	N. Fk. American	0.39	5-23-58	22
	No. 7	N. Fk. American	2/ 0.80	9-19-58	17
Castle Creek	No. 1	So. Fk. Yuba	3.96	5-18-57	3/ 352
Sagehen Cr.	No. 1	Truckee	4/ 10.9	10-21-57	53

1/ Subject to revision after final field check of areas.

2/ Revised July, 1960.

3/ 240 samples taken at gaging station; 112 samples taken elsewhere in basin.

4/ Revised.

Table 3.--Forest conditions, Castle Creek basin

ITEM	ACREAGE SAMPLED	PERCENT OF AREA
FOREST OPENINGS		
Less than 132 feet across[1/]	614.3	24.0
Less than 132 feet across[2/]	3.5	0.1
132-263 feet across	37.1	1.4
264-527 feet across	124.2	4.9
528-1,056 feet across	129.8	5.1
>1,056 feet across	1,069.0	41.8
Total	1,977.9	[3/] 77.3
FOREST DENSITY		
0-14 percent	1,363.6	53.2
15-39 percent	462.7	18.1
40-69 percent	570.7	22.3
70-100 percent	163.0	6.4
Total	2,560.0	100.0
CONDITIONS IN OPENINGS[4/]		
Grass-Herb	97.8	7.2
Brush	359.6	26.4
Trees	105.4	7.7
Crops	0.0	0.0
Rock-Ground	689.0	50.5
Talus	91.8	6.7
Roads	2.7	0.2
Buildings	0.0	0.0
Streams	11.0	0.8
Lakes	6.3	0.5
Swamps	0.0	0.0
Total	1,363.6	100.0
SLOPE		
0-10 percent		23.4
11-20 percent		40.6
21-30 percent		12.5
31-40 percent		9.4
41-50 percent		7.8
51-60 percent		1.6
61-70 percent		1.6
over 71 percent		3.1
Total		100.0
SLOPE DIRECTION		
North		12.5
East		15.6
South		43.8
West		28.1
Level		0.0
Total		100.0

1/ Collectively determined.
2/ Individually measured openings consisted of roads and streams.
3/ Percent of total area.
4/ Openings greater than 132 feet across.

Table 4.--Meteorological, snow, and soil moisture records taken and status of data processing

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
H Headquarters, CSSL	Precipitation	Recording gage	Continuous	12-4-56	6-30-60	Hourly tabulations made; published by U. S. Weather Bureau in "Hourly Precipitation Data."
	Snowfall	Snow Board	Daily, Winter season	10-31-56	6-30-60	Plotted, cumulatively.
	Snowpack	Mt. Rose snow sampler	Daily, 0800 Winter season	10-31-56	6-30-60	Plotted on graph.
	Air Temperature					
	Max. & Min.	Thermometers	Daily, 0800	10-1-56	6-30-60	Plotted on graph.
	Max. & Min.	Thermograph	Continuous	11-9-56	6-30-60	Not tabulated.
	Current	Thermometers	Daily, 0800	10-1-56	6-30-60	Not tabulated.
		Thermograph	Continuous	11-9-56	6-30-60	Not tabulated.
	Air Moisture	Psychrometer	Daily, 0800	10-1-56	6-30-60	Not tabulated.
	Air Moisture	Hygrograph	Continuous	11-9-56	6-30-60	Air moisture at time of max. temp. plotted on graph.
	Atmospheric Pressure	Merc. Barometer	Weekly	1-24-57	6-30-60	Not tabulated.
	Atmospheric Pressure	Barograph	Continuous	2-1-57	6-30-60	Not tabulated.

Table 4.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
M	Precipitation	Recording gage	Continuous	4-19-58	6-30-60	Not tabulated.
Upper Meadow Castle Creek	Snowfall	Snow Board	Bi-weekly, Winter season	10-31-56	6-30-60	Not tabulated.
	Snowpack	Mt. Rose snow sampler	Bi-weekly, Winter season	10-31-56	6-30-60	Tabulated, State reports.
	Air Temperature					
	Max. & Min.	Thermometers	Bi-weekly	12-26-56	6-30-60	Not tabulated.
	Max. & Min.	Thermograph	Continuous	12-26-56	1-4-60	Not tabulated.
	Air Moisture	Hygrograph	Continuous	12-26-56	1-4-60	Not tabulated.
O						
Onion Creek	Precipitation	Recording gage	Continuous	10-10-57	6-30-60	Not tabulated.
	Snowfall	Snow Board	Bi-weekly, Winter season	1-10-57	6-30-60	Not tabulated.
	Snowpack	Mt. Rose snow sampler	Bi-weekly, Winter season	1-10-57	6-30-60	Tabulated, State reports.
	Air Temperature					
	Max. & Min.	Thermometers	Bi-weekly	1-10-57	6-30-60	Not tabulated.
	Max. & Min.	Thermograph	Continuous	4-16-58	6-30-60	Not tabulated.
	Current	Thermograph	Continuous	4-16-58	6-30-60	Not tabulated.
	Air Moisture	Hygrograph	Continuous	4-16-58	6-30-60	Not tabulated.
	Soil Moisture	Nuclear Probe and Scaler	Monthly, Summer season	8-7-58	6-30-60	Reported.

Table 4.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
R Ridge	Snowfall	Snow Board	Monthly, Winter season	2-20-57	6-30-60	Not tabulated.
	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	2-20-57	6-30-60	Not tabulated.
Blue Canyon	Precipitation	Recording gage (from W. B.)	Continuous	9-1-58	6-30-60	Hourly tabulation made by W. B. Combined into monthly summary.
	Wind Speed and Direction	Esterline-Angus Recorder	Continuous	9-1-58	6-30-60	
Wishon Dam	Air Temperature Max. & Min.	Thermometers	Daily, 0745	12-5-56	6-30-60	Checked and scatter diagrams made comparing Wishon Dam with Big Creek PH #1 Grant Grove and Huntington Lake.
	Max. & Min.	Thermograph	Continuous	12-19-57	6-30-60	
	Current	Thermometers	Daily, 0745	12-5-56	6-30-60	
	Current	Thermograph	Continuous	12-19-57	6-30-60	
	Air Moisture	Psychrometer	Daily, 0745	12-5-56	6-30-60	
	Air Moisture	Hygrograph	Continuous	12-19-57	6-30-60	Not tabulated.
	Wind miles	Anemometer	Daily, 0745	12-5-56	6-30-60	Not tabulated.
	Snow Evaporation	Snow Pans	Monthly, Winter season	1-24-57	6-30-60	Tabulated and summarized.

Table 4.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
Swain Mt.	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	1-6-58	6-30-60	Reported.
	Soil Moisture Data	Nuclear Probe and Scaler	Monthly, Summer season	7-2-58	6-30-60	Reported.
Sagehen	Snowpack	Mt. Rose snow sampler	Monthly, Winter season	3-2-60	6-30-60	Not tabulated.
	Soil Moisture	Nuclear Probe and Scaler	Monthly, Summer season	7-24-58	6-30-60	Reported.

Table 5.--Monthly climatic summary, Central Sierra Snow Laboratory, 1959-1960

Month	AIR TEMPERATURES							Total precipitation	Cum. Daily Snow w.e.	Month-end Snow w.e. 1/
	Averages			Extremes						
	Max.	Min.	Mean	Highest	Date	Lowest	Date			
1959	F°	F°	F°	F°		F°		inches		
July	78.4	45.7	62.0	84	10,20,23	37	7	0.00	0.00	0.0
Aug.	73.7	41.5	57.6	84	7,10	30	21	0.12	0.00	0.0
Sept.	63.9	37.0	50.4	81	9	27	28,30	2.95	0.00	0.0
Oct.	61.1	33.6	47.4	77	24	21	29	0.11	0.00	0.0
Nov.	54.5	26.3	40.4	62	25	21	29	T	0.00	0.0
Dec.	43.3	20.1	31.7	57	1,2,3,6,7	-1	31	3.44	3.03	2.5
1960										
Jan.	30.0	17.1	23.6	41	7,30	-4	2	12.67	12.27	16.8
Feb.	35.2	15.3	25.2	45	7	5	24,29	14.80	7.69	26.5
Mar.	42.9	22.4	32.6	61	25	6	1	11.90	9.49	31.0
Apr.	46.0	24.3	35.2	62	5	14	25	3.49	3.14	16.5
May	51.9	28.4	40.2	72	31	19	22	2.81	2.21	0.0
June	73.3	40.3	56.8	82	4	33	29	T	0.00	0.0
Total								52.29	37.83	
Average	54.5	29.3	41.9							

1/ Water equivalent.

Table 6.--Computation of long-term mean sediment concentration from suspended sediment samples, Castle Creek, 1958 forest conditions

Discharge Class	Frequency	Relative Flow	No. Sediment Samples	Percent of flow in various turbidity classes, ppm: <12.5	12.5-27.5	27.5-72.5	72.5-142.5	142.5-400	Sediment Concentration: Average	Total
cfs	percent			ppm						
<1	44.00	0.0060	2	44.00	-	-	-	-	7.0	0
1-10	30.00	0.0890	15	26.00	4.00	-	-	-	8.75	0.8
10-40	14.00	0.2087	14	7.00	6.00	-	-	1.00	35.7	7.5
40-100	8.80	0.3915	6	-	7.34	1.46	-	-	25.0	9.8
100-200	2.82	0.2605	15	0.187	0.376	0.561	1.505	0.188	104.0	27.1
>200	0.38	0.0668	6	-	-	-	-	0.38	300.0	20.1
Totals	100.00	1.0225	58	-	-	-	-	-	-	-
Mean sediment concentration				7	20	5	108	300	-	65.3

Table 7a.--Snow accumulation at maximum pack on different slope and forest conditions, 7,000 feet elevation, Central Sierra Snow Laboratory, April 22, 1958[1/]

Forest	North 315°-45° Slope 15%	North 315°-45° Slope 30%	East 45°-135° Slope 15%	East 45°-135° Slope 30%	East 45°-135° Slope 60%	South 135°-225° Slope 15%	South 135°-225° Slope 30%	South 135°-225° Slope 60%	West 225°-315° Slope 15%	West 225°-315° Slope 30%	West 225°-315° Slope 60%	Level
Opening 1/2H-1H	(53.2)[2/] 32-73-M[3/]	(67.5) 16-73-M	(47.1) 8-76-L	(51.8) 18-67-M		(52.9) 29-73-M	(47.0) 5-77-L		(57.1) 6-74-L	(56.6) 2-74-L	(50.9) 21-62-L	(62.2) 31-61-L
Opening 1H-2H	(67.8) 30-73-M	(69.2) 11-74-M	(59.4) 26-78-L	(52.9) 15-72-S		(55.9) 27-75-S	(51.0) 24-67-S		(57.8) 17-73-M	(60.5) 20-63-M		(58.2) 3-76-L
Opening 2H-4H	(60.4) 7-76-L		(60.0) 28-75-M				(56.9) 14-72-M		(62.2) 9-75-S			(63.6) 19-72-S
Opening >4H		(76.0) 12-77-S		(68.4) 4-75-L		(58.5) 1-70-L			(60.9) 23-63-L			(63.9) 10-71-M
Density 20-50%	(65.0) 7-73-M	(62.0) 14-75-M	(58.0) 16-75-S	(51.0) 19-77-L		(58.0) 29-66-L			(58.0) 11-73-S	(58.0) 22-69-M		(51.0) 17-74-M
Density 50-80%	(48.0) 6-74-M	(62.0) 5-72-M	(44.0) 2-76-L	(45.0) 23-70-M	(54.0) 4-76-L	(50.0) 15-75-M	(46.0) 8-76-L		(59.0) 12-74-M	(52.0) 10-73-M		(41.0) 3-76-L
Density 80-100%		(45.0) 26-67-M	(53.0) 24-67-M	(52.0) 25-67-M		(52.0) 9-78-L	(42.0) 20-78-M	(48.0) 21-76-L	(48.0) 28-67-L			(49.0) 27-67-L

1/ About 6 inches of ablation had taken place by April 22, 1958.

2/ Values in parenthesis are average snow water considering 50-50 forest and open in the "opening courses" and course average in the "density courses".

3/ Snow course number, elevation in 100's of feet and tree size: L=Large, over 100 feet high, M=Medium, 60-100 feet high, and S=Small, less than 60 feet high.

Table 7b.--Snow accumulation at maximum pack on different slope and forest conditions, 7,000 feet elevation, Central Sierra Snow Laboratory, April 1, 1959

Forest	North 315°-45° Slope 15%	North 315°-45° Slope 30%	East 45°-135° Slope 15%	East 45°-135° Slope 30%	East 45°-135° Slope 60%	South 135°-225° Slope 15%	South 135°-225° Slope 30%	South 135°-225° Slope 60%	West 225°-315° Slope 15%	West 225°-315° Slope 30%	West 225°-315° Slope 60%	Level
Opening 1/2H-1H 1/ 2/	(26.6) 32-72-M (24.5) B-73-M	(26.1) D-76-L	(18.0) 8-74-L	(20.4) 18-67-M		(20.2) A-73-M (21.8) 29-73-M	(15.0) 5-77-L		(24.6) 6-74-L	(19.6) C-76-L (23.8) 2-74-L	(20.6) 21-62-L	(27.6) 31-61-L
Opening 1H-2H	(29.1) 30-73-M	(28.9) 16-73-M (30.0) 11-74-M	(23.6) 26-78-L	(22.6) 15-72-S		(19.8) 27-75-S	(17.8) 24-67-S		(26.7) 17-73-M	(26.6) 20-63-M		(25.0) 3-76-L
Opening 2H-4H	(24.0) 7-76-L		(28.1) 28-75-M				(18.8) 14-72-M		(28.4) 9-73-S			(23.2) 19-72-S
Opening >4H Av.		(36.4) 12-77-S		(28.6) 4-75-L		(21.1) 1-70-L			(26.1) 23-63-L			(28.0) 10-71-M
Density 20-50%	(30.7) 7-73-M	(23.7) 5-72-M (29.5) 14-75-M	(21.9) 16-75-S	(18.9) 19-77-L	(33.6) 1-75-L	(25.0) A-70-M (22.2) 29-66-L	(15.0) 13-74-L		(23.8) 11-73-S	(15.6) 10-73-M (20.8) 22-69-M		(22.2) 17-74-M
Density 50-80%	(22.6) 6-74-M (31.2) 32-61-L	(23.6) 31-70-L	(12.9) 2-76-L	(17.8) 23-70-M	(18.5) 4-76-L	(18.3) B-70-M (20.9) 15-75-M	(17.6) 8-76-L		(25.2) 12-74-M	(18.5) 18-73-M		(16.2) 3-76-L
Density 80-100%	(20.4) 30-70-S	(12.5) 26-67-M	(17.2) 24-67-M	(17.3) 25-67-M		(16.0) 9-78-L	(13.5) 20-78-M	(18.1) 21-76-L	(15.6) 28-67-L			(16.1) 27-67-L

1/ Numbers in parentheses are average snow water considering 50-50 forest and open in the "opening courses" and course average in the "density courses".

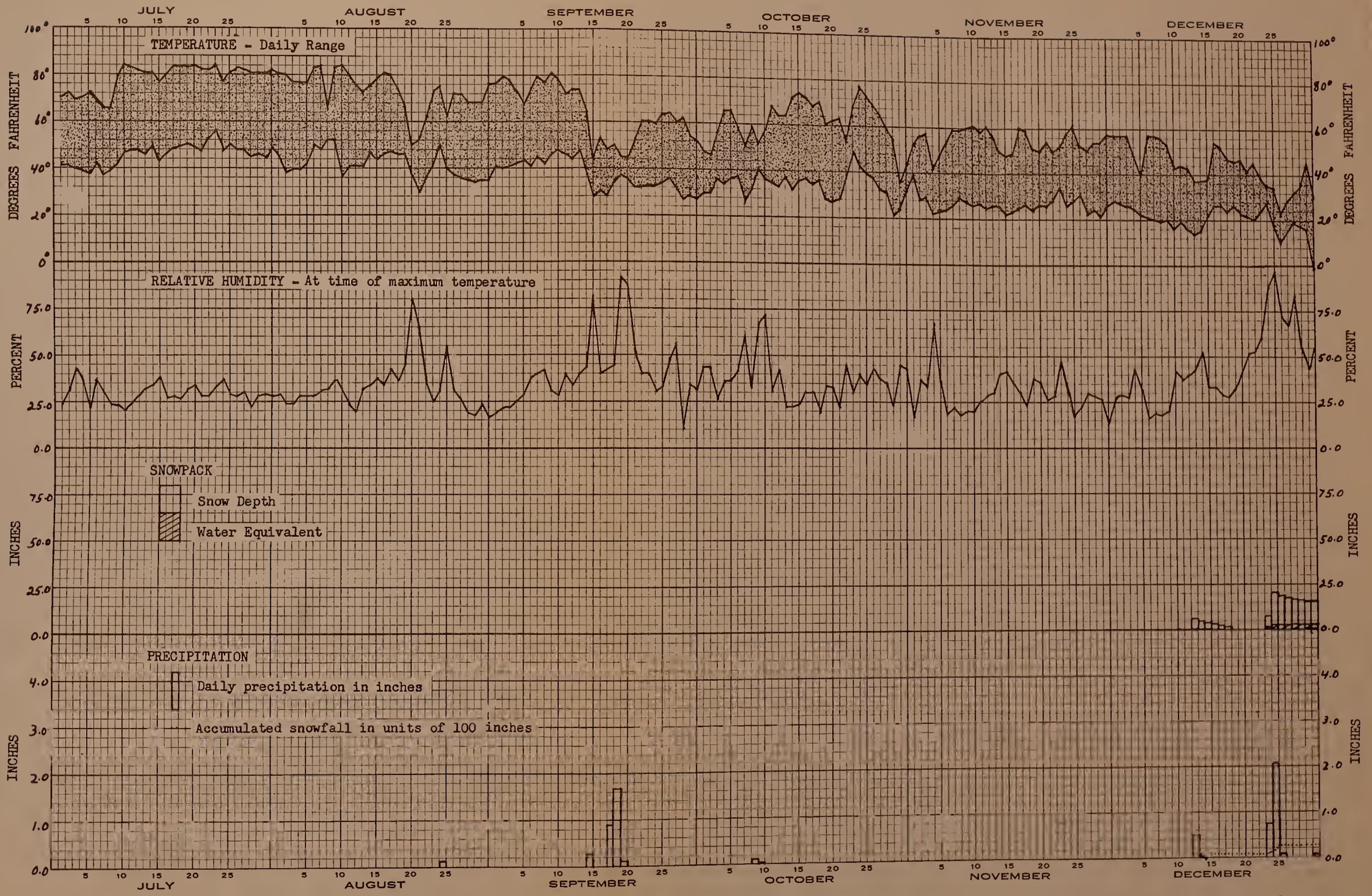
2/ Snow course number, elevation in 100's of feet and tree size: L=Large, over 100 feet high, M=Medium, 60-100 feet high, and S=Small, less than 60 feet high.

APPENDIX B

FIGURES 2-5

Synopsis of Hydrometeorological Elements – 1959-1960, Central Sierra Snow Laboratory

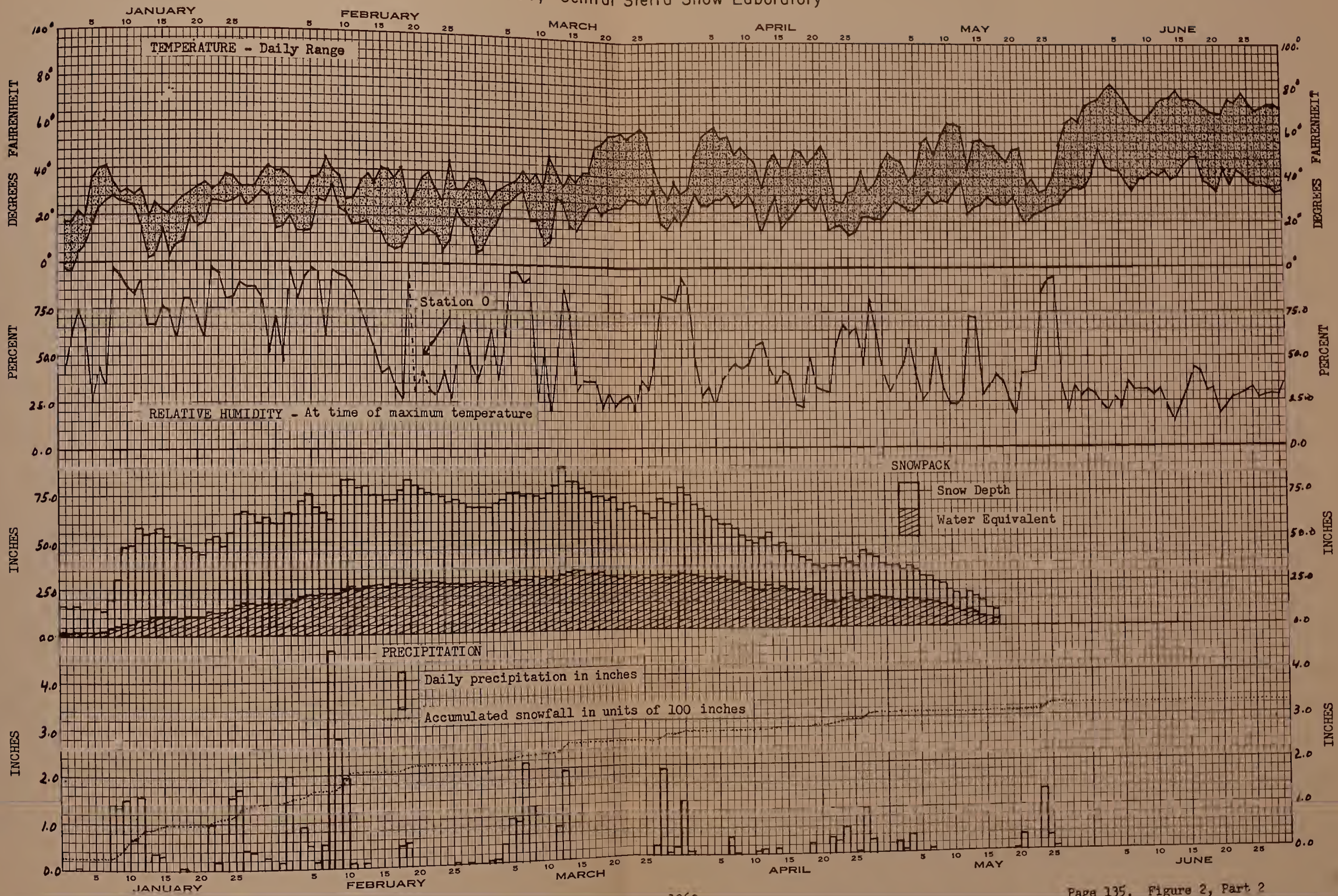
MSH & LGR
July, 1960



1959

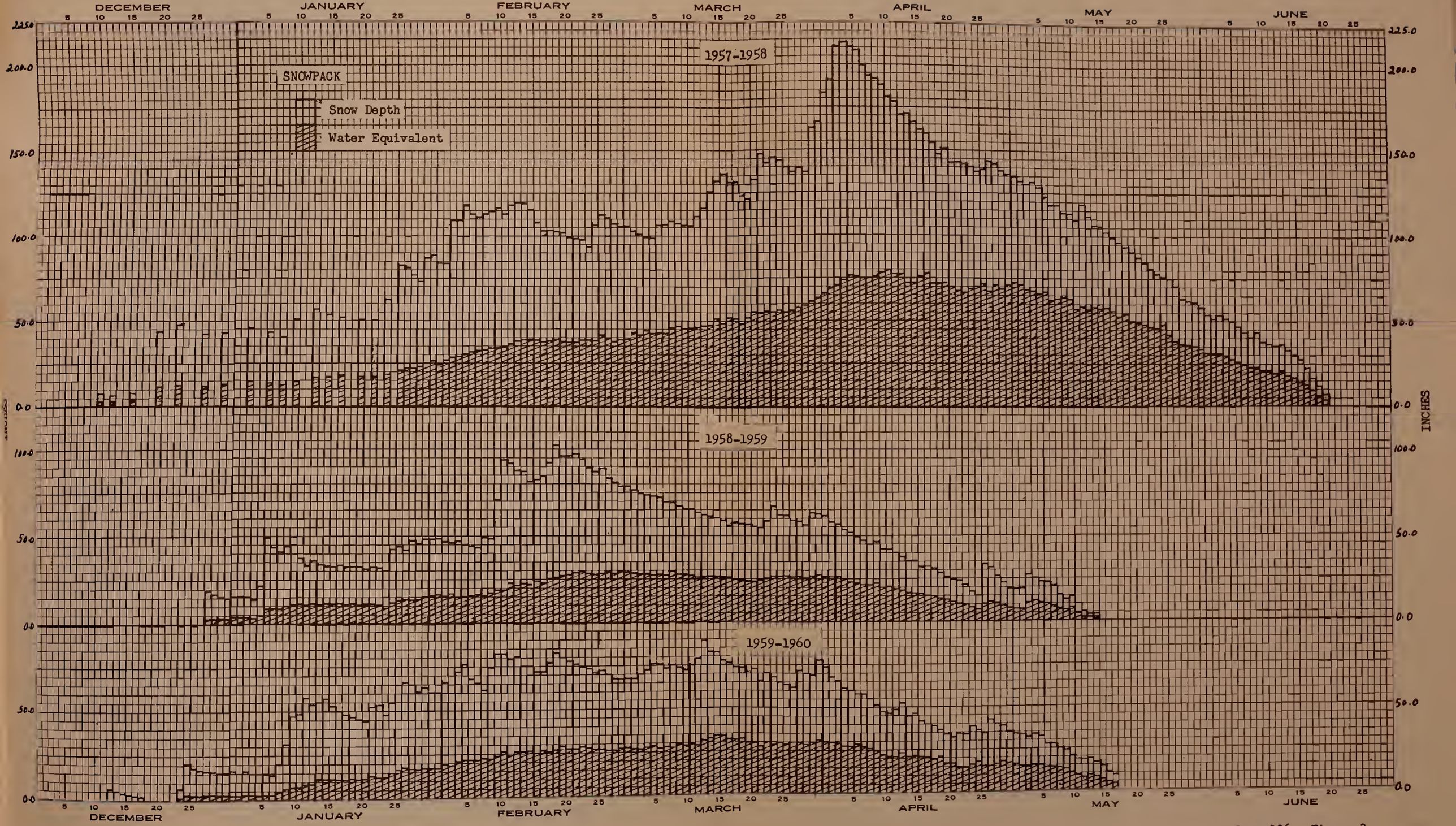
Synopsis of Hydrometeorological Elements - 1959-1960, Central Sierra Snow Laboratory

MSH & LGR
July, 1960



Comparison of Daily Snowpack – 1958, 1959, 1960. Central Sierra Snow Laboratory, Headquarters.

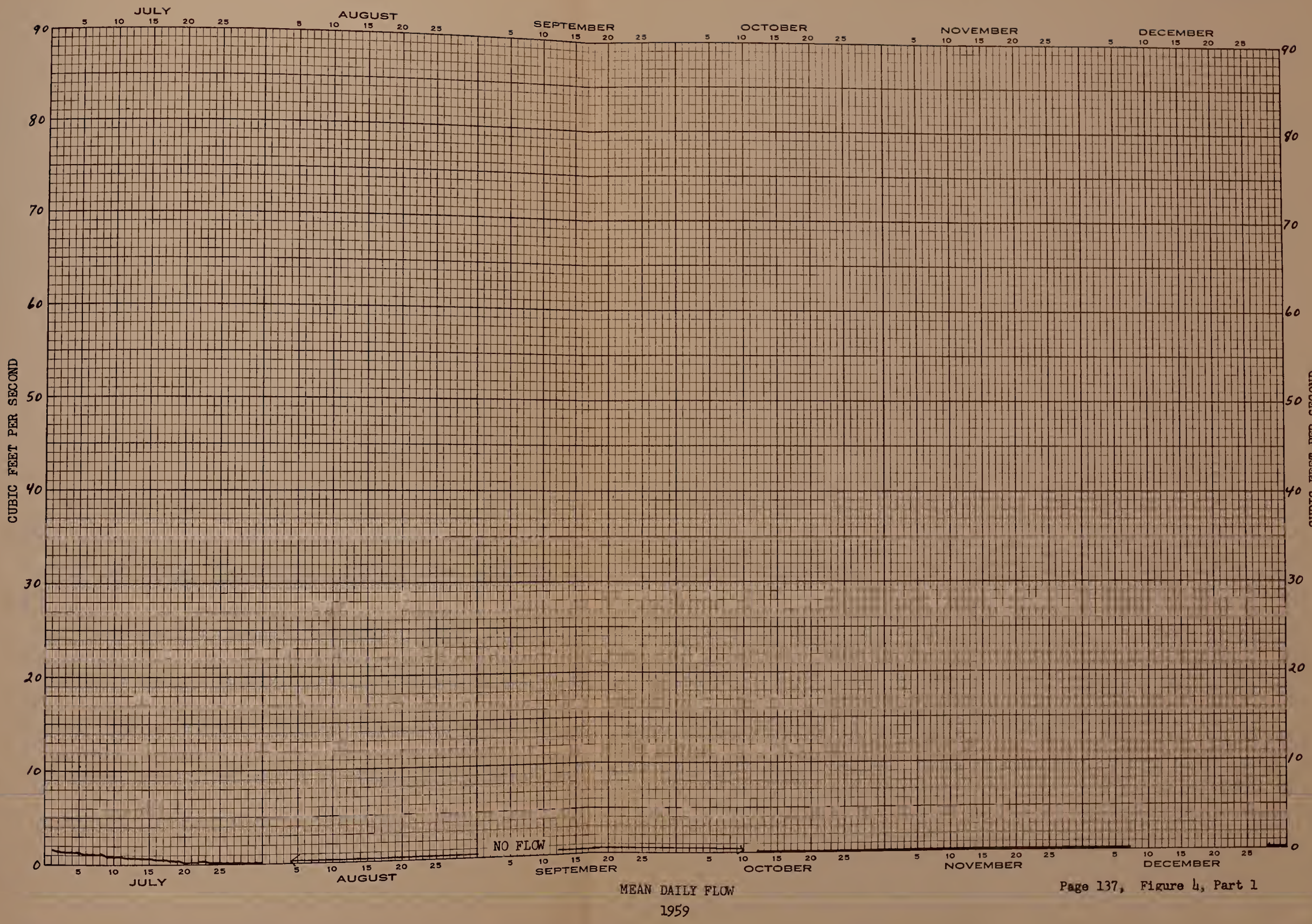
MSH & LGR
July, 1960



Page 136, Figure 3

Streamflow, Castle Creek, 1959-1960

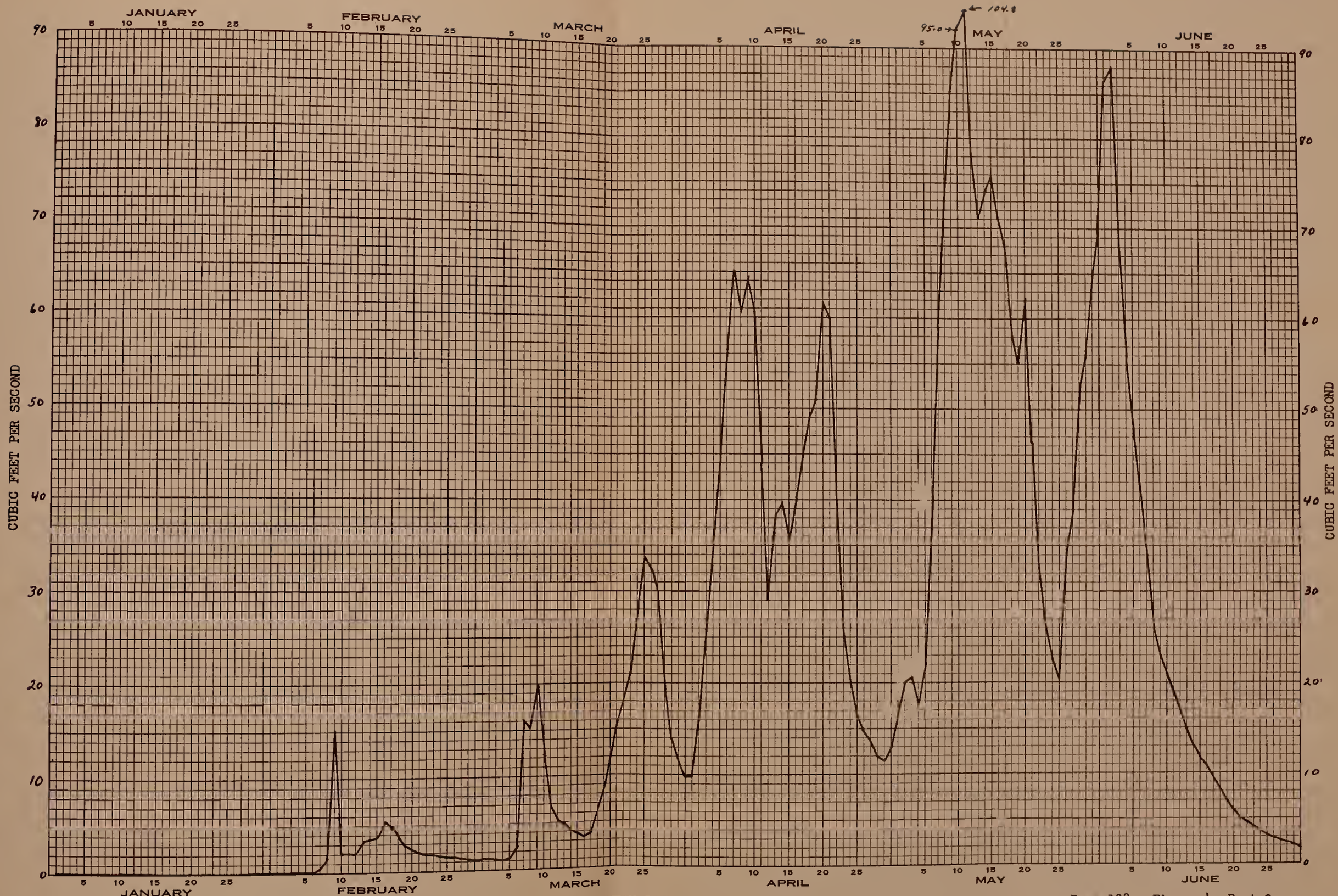
MSH & LGR
Sept., 1960



MEAN DAILY FLOW
1959

Streamflow, Castle Creek, 1959-1960

MSH & LGR
Sept., 1960



MEAN DAILY FLOW
1960

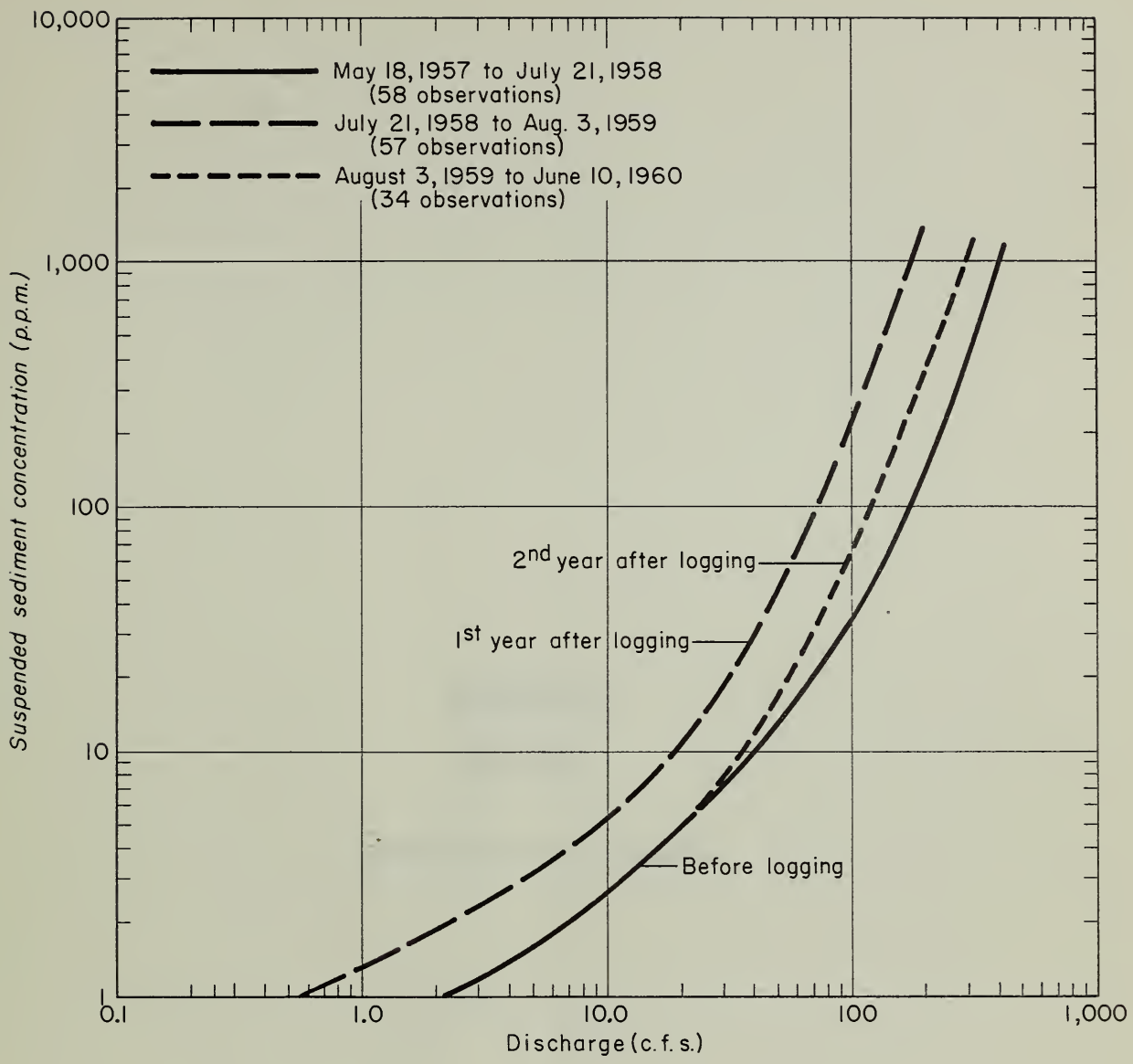


Figure 5 – Suspended sediment, Castle Creek, before and after logging.

APPENDIX C

REPRINTS

1959-1960 Publications